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SEA TRIAL PERFORMANCE EVALUATION OF THE FATHOM FLEXNOSE® FAIRING

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

SEA TRIAL PERFORMANCE EVALUATI N OF THE FATHOM FLEXNOSE® FAIRING

by

Raymond P. Fara

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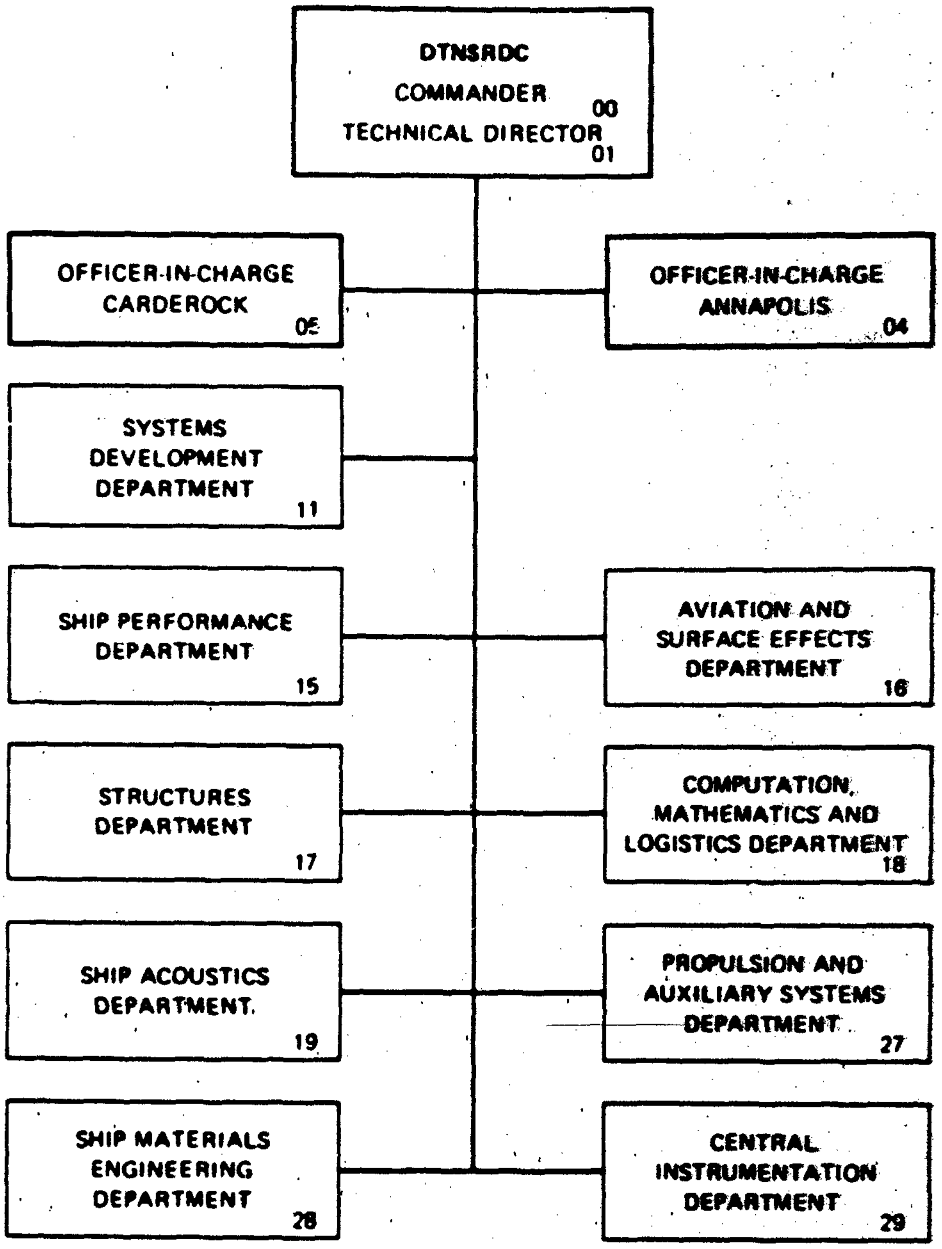

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An evaluation of a low-drag cable fairing was undertaken in response to the need for a towing capability at deep depths at high speed. The objective of the at-sea evaluation was to establish whether the Fathom Flexnose® fairing would meet deep-depth at high-speed requirements. Observations made during the sea trial revealed severe towline skew angles until modifications were made to the towline. The modifications, which consisted of the addition of fairing support rings to the towline at short intervals, resulted in a reduction of skew angle to within operational requirements.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF TABLES

ABSTRACT

An evaluation of a low-drag cable fairing was undertaken in response to the need for a towing capability at deep depths at high speed. The objective of the at-sea evaluation was to establish whether the Fathom Flexnose® fairing would meet deep-depth at high-speed requirements. Observations made during the sea trial revealed severe towline skew angles until modifications were made to the towline. The modifications, which consisted of the addition of fairing support rings to the towline at short intervals, resulted in a reduction of skew angle to within operational requirements.

ADMINISTRATIVE INFORMATION

The research and development program described in this report was funded by the Naval Electronic Systems Command under Program Elements 64502N, Task Area X0742, David Taylor Naval Ship Research and Development Center Work Unit 1-1548-408.

INTRODUCTION

In response to the need for a towing capability at deep depths at high speeds, the David Taylor Naval Ship Research and Development Center (DTNSRDC) undertook an evaluation of a low-drag cable fairing. The fairing was manufactured by Fathom Oceanology, Limited of Point Credit, Ontario, Canada with the trademark of "Flexnose." The Center purchased 1000 ft (305m) of Flexnose fairing for a 0.347-in. (8.8-mm) diameter cable. The towline was evaluated aboard the Center's high-speed research ship R/V ATHENA.

The objectives of the at-sea evaluation were to establish that the Fathom Flexnose fairing would tow with acceptable kiting, have low drag, and be durable enough to withstand sustained high-speed operations.

This report describes an experimental evaluation of the hydrodynamic performance of the Flexnose fairing. Descriptions of the fairing, the instrumentation, and the experimental arrangement and procedure are presented. The results include tension at the depressor, towline angle at the depressor, depressor depth, depressor pitch angle, tension at the ship, towline angle at the ship, and skew angle as functions of speed. Finally, conclusions are drawn as to the overall performance of the towline.

® Trademark of Fathom Oceanology, Ltd.

TOWLINE DESCRIPTION

The cable used in the evaluation was a 0.347-in. (8.8-mm) diameter, double armored, galvanized, improved plow steel, electromechanical cable with nine inner-core electrical conductors. The cable was faired with 1000 ft (305m) of Fathom Flexnose fairing sections. The physical characteristics of the cable and fairing are presented in Table 1. Each fairing section is composed of four pieces as shown in Figure 1a. A 1-foot length of assembled fairing is shown in Figure 1b. The fairing section shape is shown in Figure 2 along with specified offsets.

TABLE 1 - PHYSICAL CHARACTERISTICS OF THE TOWLINE

Cable	
Diameter	0.347 in. (8.8 mm)
Weight in Water	0.159 lb/ft (2.366×10^{-1} kg/m)
Length	1200 ft. (366m)
Electrical Conductors	8 - AWG - #22
	1 - AWG - #18
Fairing Section	
Length	2.0 in. (50.8 mm)
Chord	2.65 in. (67.3 mm)
Maximum Thickness	0.5 in. (12.7 mm)
Weight in Water	0.031 lb/ft (4.613×10^{-2} kg/m)
Shape Specification Numbers	Nose - FN-500-358-1
	Tail - FT-500-1
	Link - FL-500

DATA ACQUISITION SYSTEM

The data acquisition system, shown schematically in Figure 3, consisted of transducers to measure towline tension at the depressor, towline angle at the depressor, depressor pitch, depressor depth, towline tension at the ship, towline angle at the ship, towline skew angle relative to the ship heading, and ship speed. The type, range, and accuracy of these transducers are presented in Table 2. The transducers were connected to a multichannel voltage-controlled oscillator unit, which combined all the sensor signals into one composite signal

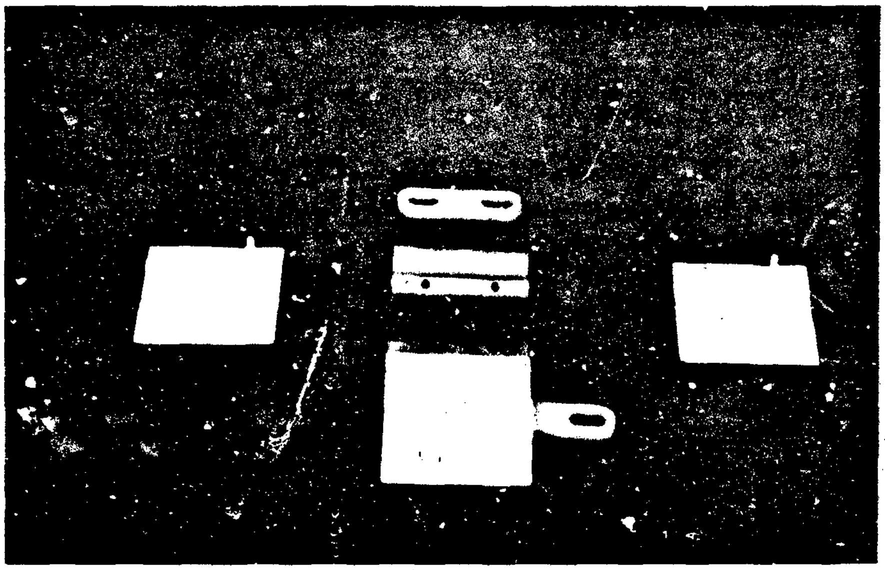

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Figure 1a - Fairing Section Components

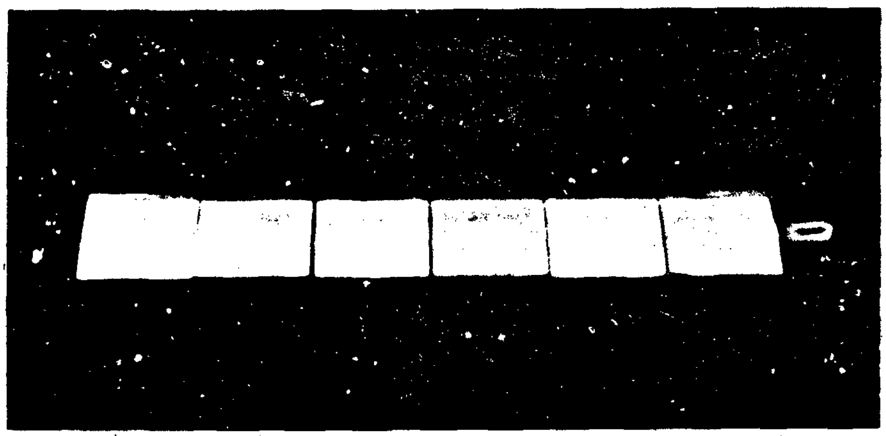
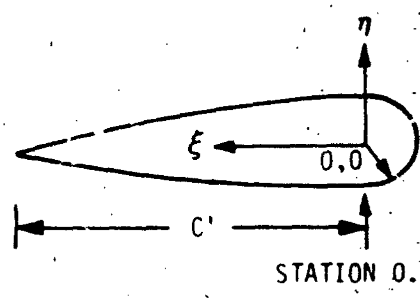


Fig :re 1b - Sample of Flexnose Fairing (1-Foot Long)

Figure 1 - Fathom Flexnose Fairing Components and Assembly



$$\xi = \frac{x}{C'} \qquad \eta = \frac{y}{C'}$$

Station	Offsets			
	x	ξ	y	η
1*	0.000	0.000	.250	.10416
2*	0.700	0.29167	.250	.10416
3	0.800	0.33333	.249	.103750
4	0.900	0.37500	.248	.103333
5	1.000	0.41667	.245	.102083
6	1.100	0.45833	.241	.100417
7	1.200	0.50000	.237	.098750
8	1.300	0.54167	.230	.095833
9	1.400	0.58333	.223	.092917
10	1.500	0.62500	.211	.087917
11	1.600	0.66667	.198	.082500
12	1.700	0.70833	.184	.076667
13	1.800	0.75000	.167	.069583
14	1.900	0.79167	.147	.061250
15	2.000	0.83333	.127	.052917
16	2.100	0.87500	.105	.043750
17	2.200	0.91667	.080	.033333
18	2.300	0.95833	.051	.021258
19	2.400	1.000	.000	.000

* Straight section

Figure 2 - Fairing Section Shape

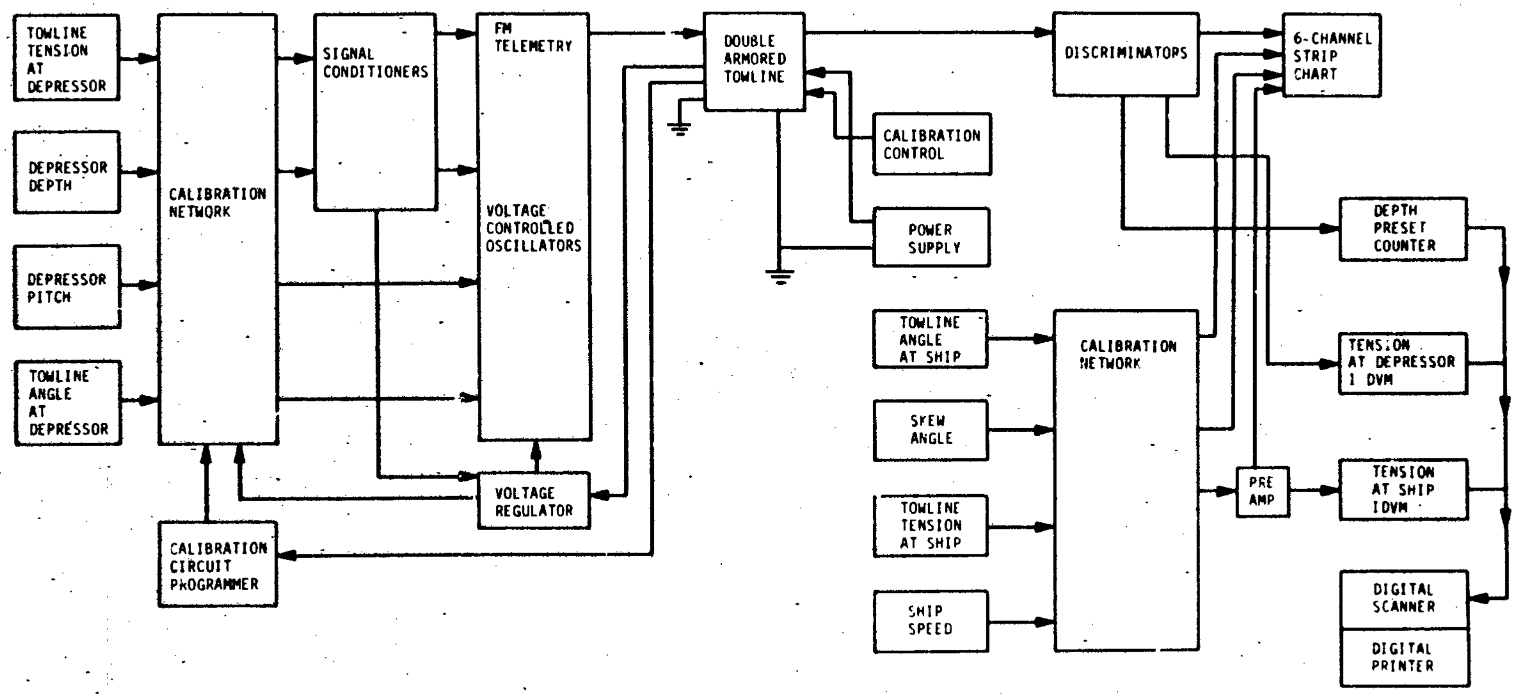


Figure 3 - Block Diagram of Data Acquisition System

TABLE 2 - MEASUREMENT SYSTEM TRANSDUCER CHARACTERISTICS

Measurement	Transducer Type	Range	Accuracy
Towline Tension at Depressor	Strain Gage Proving Ring	0 - 4,000 pounds	±20 pounds
		0 - 17,800 newtons	±90 newtons
Towline Angle at Depressor	Pendulous Potentiometer	±20°	±1/2°
Depressor Pitch	Pendulous Potentiometer	±10°	±1/2°
Depressor Depth	Strain Gage Pressure Sensor	0 - 1,129 feet	±3 feet
		0 - 344 meters	±1 meter
Towline Tension at Ship	Strain Gage Load Cell	0 - 5,000 pounds	±25 pounds
		0 - 22,240 newtons	±110 newtons
Towline Angle at Ship	Pendulous Potentiometer	±45°	±1/2°
Skew Angle	Potentiometer	±40°	±1/2°
Ship Speed	E-M Log	0 - 40 knots	±1/2 knot

for transmission through the towline to the shipboard instrumentation. An FM discriminator aboard ship separated the composite signal into component signals proportional to those at the individual sensors. These were graphically or digitally recorded as shown in the block diagram (Figure 3).

The kite angle, which is the angle the towline projects port or starboard of the ship's centerline onto the transverse vertical plane, was not measured directly. Rather, measurements were made of the towline angle, and the skew angle which is the angle the towline projects port or starboard of the ships centerline onto the horizontal plane. The towline angle ϕ, kite angle β, and skew angle ψ are shown schematically in Figure 4. The kite angle is related to the skew angle by the following:

$$\beta = \tan^{-1} \frac{\sin \psi}{\tan \phi}$$

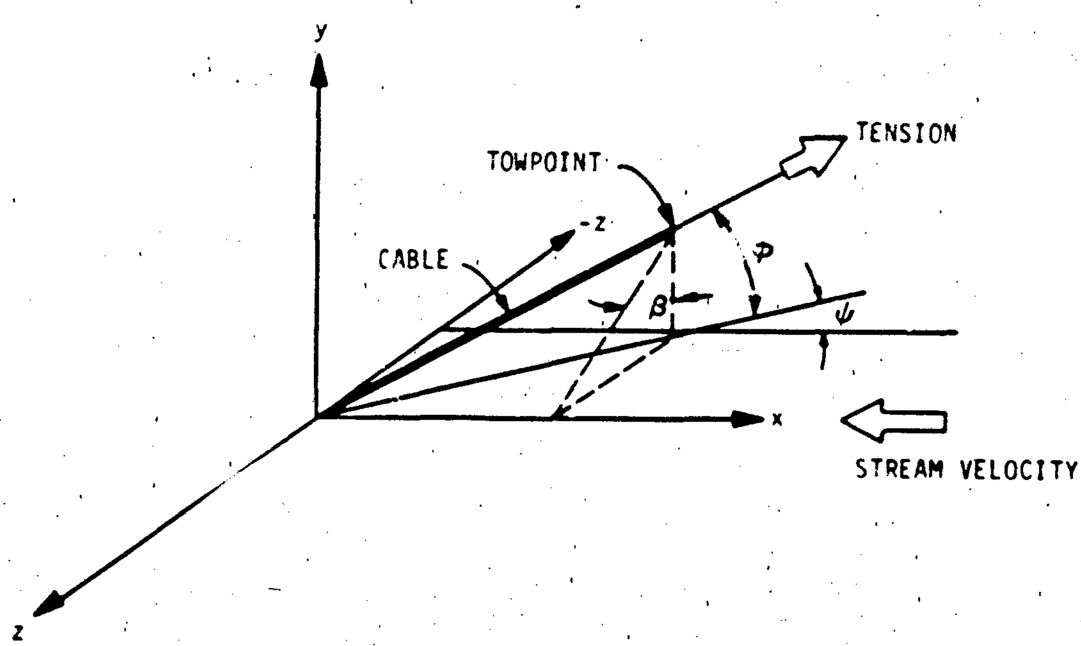


Figure 4 - Schematic Showing Relationship Between Skew Angle ψ and Kite Angle β

MECHANICAL EQUIPMENT AND PROCEDURE

The evaluation was conducted in The Gulf of Mexico aboard R/V ATHENA. A sketch of the towing arrangement is shown in Figure 5. The winch drum on the ship

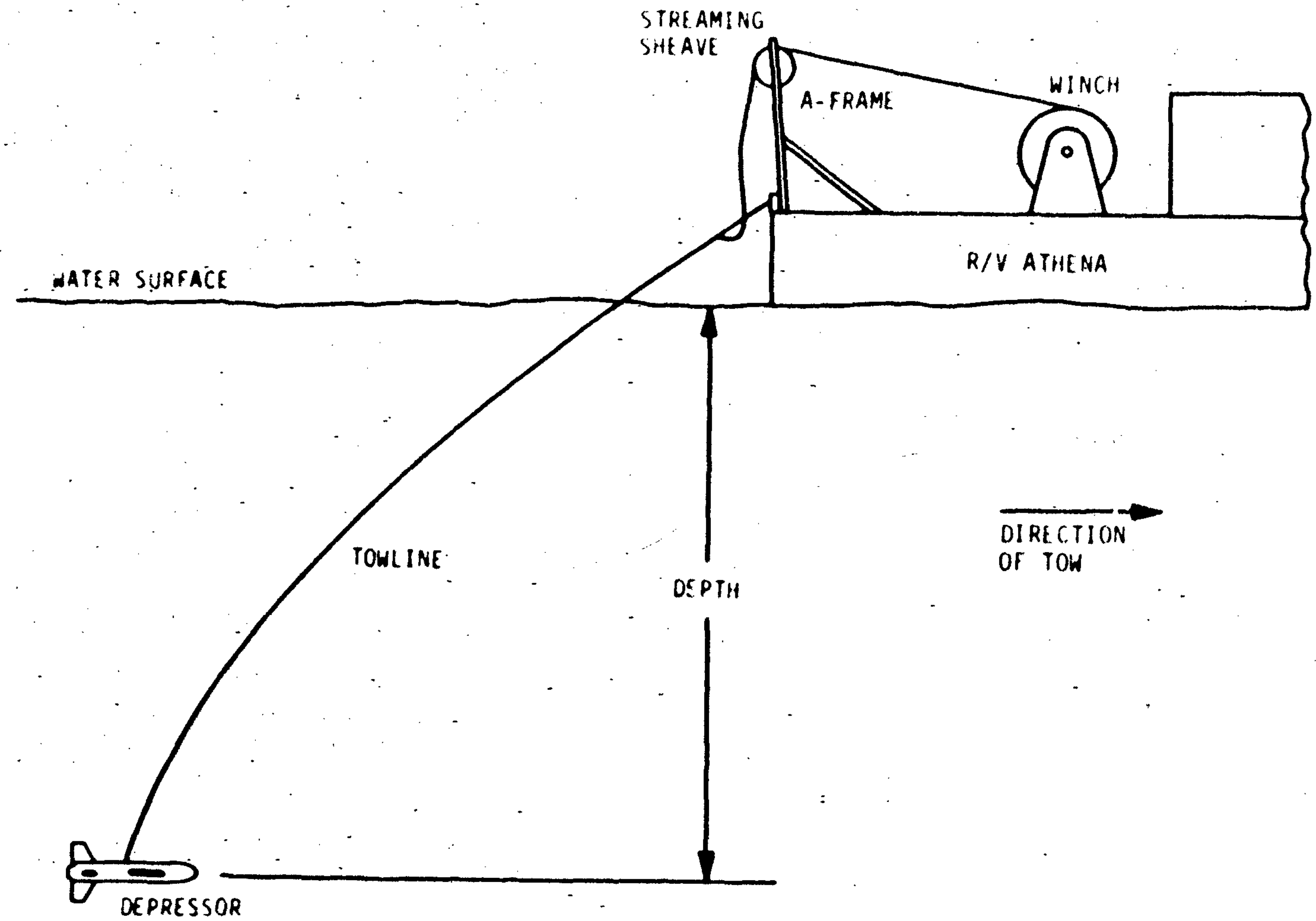


Figure 5 - Schematic of the Towing Arrangement

was provided with a plastic grooved surface about which the towline was wrapped. The groove, which matched the shape of the leading edge of the towline fairing, is shown in Figure 6. The purpose of the groove was to minimize any damage to the fairing during reeling operations and storage. The winch drum with the towline stored is shown in Figure 7.

An A-frame and sheave installed on the ship fantail provided a means to launch and retrieve the depressor and the towline. The A-frame and sheave are shown in Figure 8. The depressor body used for the experiments is shown in Figure 9. The lift force of the depressor can be varied by manually changing the angle of incidence of the depressor wing.

The experiments were conducted with a depressor wing incidence setting of 5.33 deg (leading edge down) and towline scopes of 229 and 429 ft (69.8 and 130.8m) measured from the ship attachment point.

Towing was varied from 12.5 to 25 knots. Reciprocal headings were run at the longer towline scopes. Midway through the experiments, fairing support rings were added to the cable at intervals of 10 ft (3m) for the first 100 ft (30.5m) nearest the depressor and then in 15-ft (4.6-m) intervals for the remaining cable up to a total length of 421 ft (128.3m). The rings consisted of 1-in. (25.4-mm) lengths of split PVC tubing, with an inside diameter slightly smaller than the diameter of the cable, that were epoxied to the cable and held in place with stainless-steel banding straps. The rings were added to transfer the tangential hydrodynamic loading from the fairing to the cable.

Following the data runs, an endurance evaluation was conducted at 25 knots for 4 hours to obtain an indication of the durability of the fairing and to ascertain consistent kiting performance with time. The towline was inspected after 2-hour and 4-hour towing intervals.

RESULTS

There were no problems with reeling the towline off the winch drum; however, some tearing of the fairing nose piece occurred during retrieval of the towline whenever the leading edge of the nose piece came into contact with the trailing edge of the previous wrap. This problem could be solved through use of the proper level winding arrangement.

Observations of towline performance prior to the addition of support rings revealed increasing values of skew angle with time. Skew increased to both port

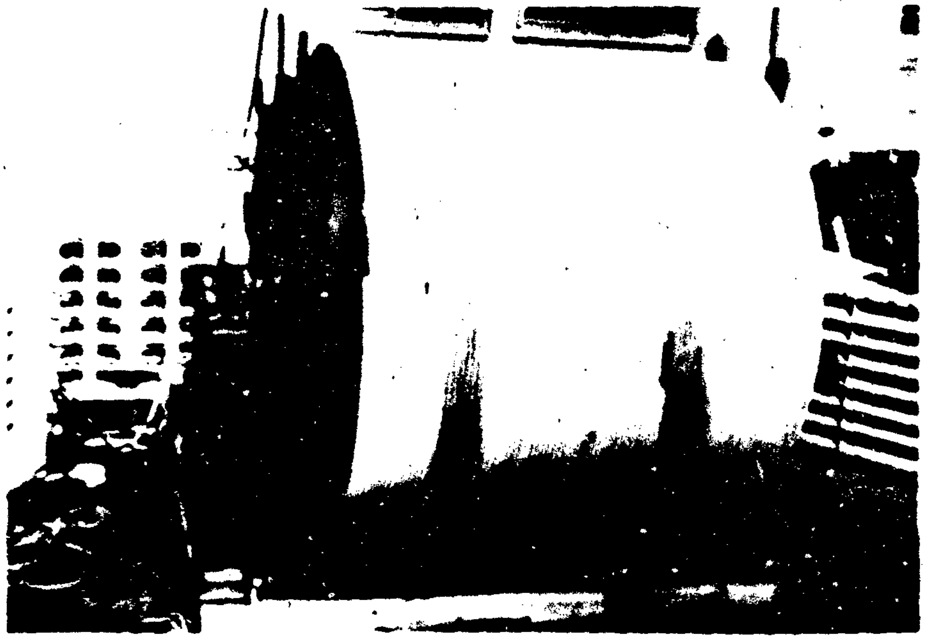


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Figure 6 - Winch Drum with Extrusion

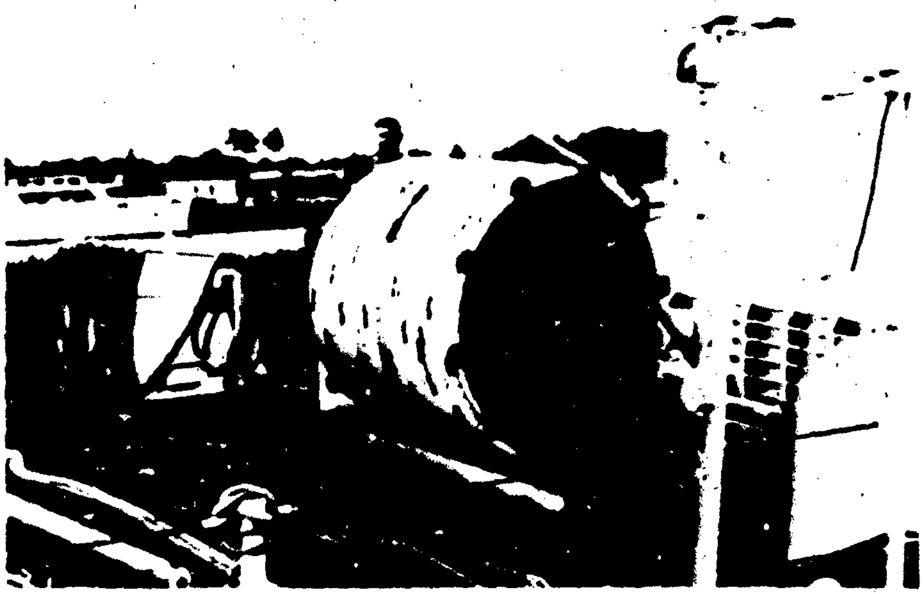

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Figure 7 - Winch Drum with Stored Towline

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Figure 8 - A-Frame and Sheave

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Figure 9 - Depressor Body

and starboard from virtually zero up to 30 degrees within 1 hour of towing at the higher speeds. The severe and time varying skew angles observed were believed to be a result of the inability of the fairing sections to effectively transfer the tangential hydrodynamic forces to the cable. These forces, which increase with increased scope and speed, induced jamming and interference between fairing sections (called stacking) which eventually prevented the fairing from freely swiveling on the cable. The installation of rings at short intervals transferred the tangential force from the fairing to the cable to keep the stacking force to a minimum and thus improved the ability of the fairing to free swivel and, therefore, align itself with the flow.

Following the addition of support rings, the skew angle was reduced in magnitude and remained time invariant. At speeds below 18 knots, the towline skew-angle varied as a function of speed from 0 to 20 degrees to port while at speeds above 18 knots the towline skew angle varied from 0 to 20 degrees to starboard. The measured towline skew angle with support rings is presented as a function of speed in Figure 10.

The measured towline skew angles with support rings are acceptable for towing from surface ships; however, when towing from a submarine these skew angles may possibly damage the fairing where the towline comes in contact with the longitudinal rollers on the doors. The skew angles may be caused by an asymmetry in the fairing sections or friction in the support rings under higher loads. Kiting may be reduced by reducing any manufacturing asymmetry and/or improving the support rings.

The fairing survived adequately during extended towing. No visible damage was sustained during approximately 10 hours of total towing time, over 5 hours at a speed of 25 knots. Towline tension and angle at the depressor and depressor pitch angle are presented as functions of speed in Figures 11 through 13. The towline tension and angle at the depressor along with assumed towline hydrodynamic loading functions were used as input into a Flexible Cable Program[1] to determine the drag coefficient for the towline. The hydrodynamic loading functions used were obtained by Walton[2] for a sectional fairing of similar shape.

[1] A complete listing of references is given on page 26.

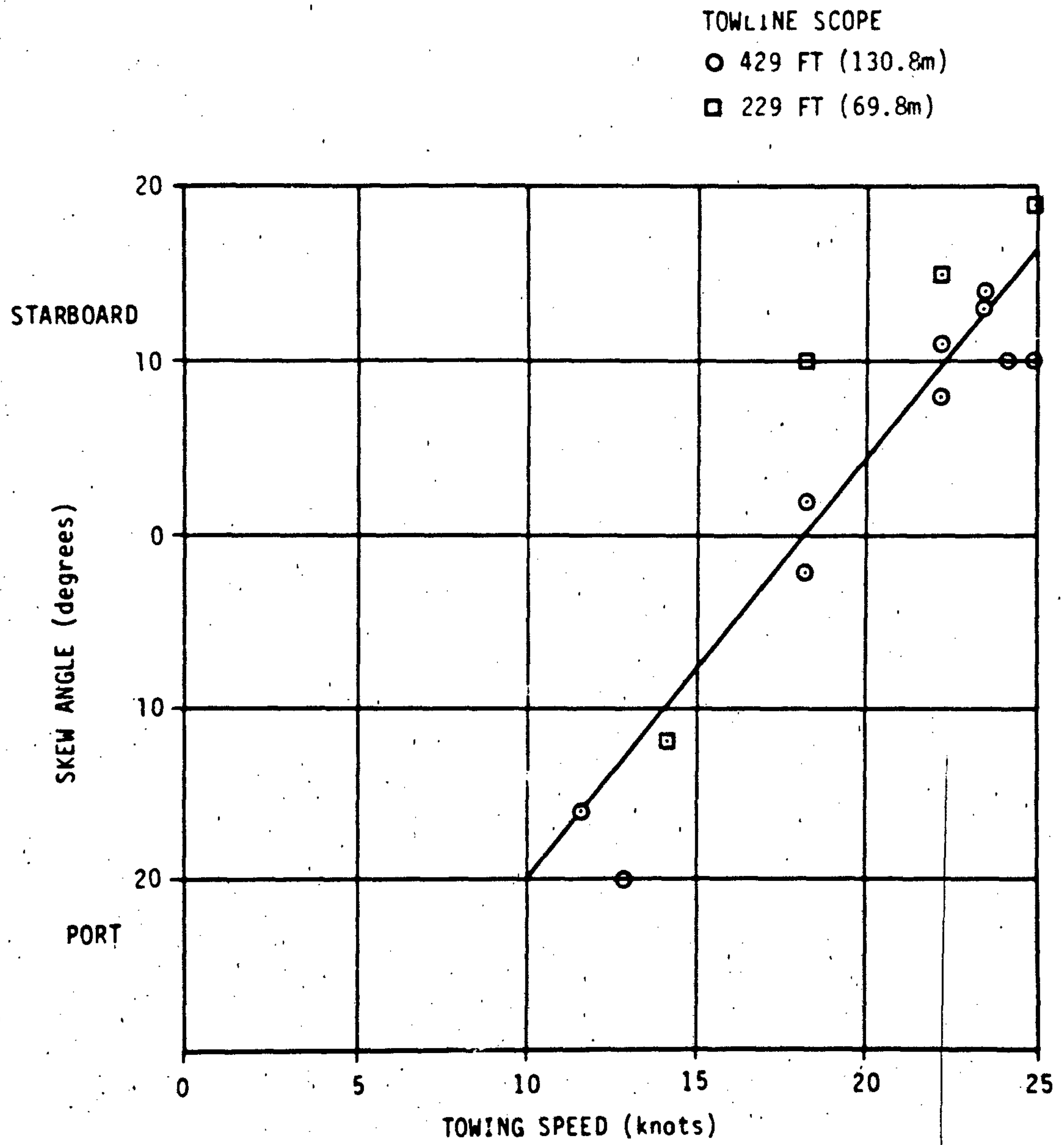

Figure 10 - Skew Angle as a Function of Speed with Support Rings Added to the Towline

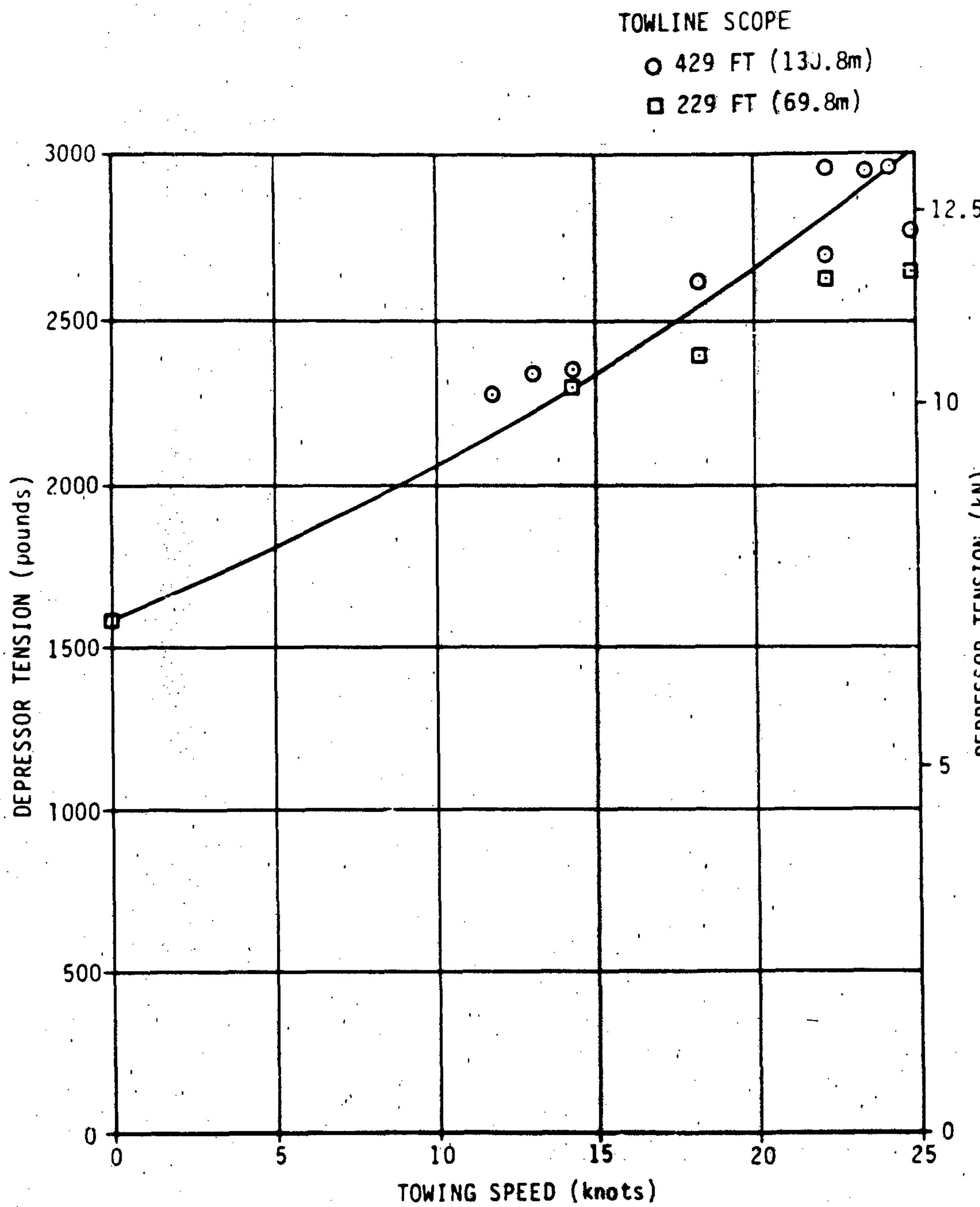

Figure 11 - Depressor Tension as a Function of Speed

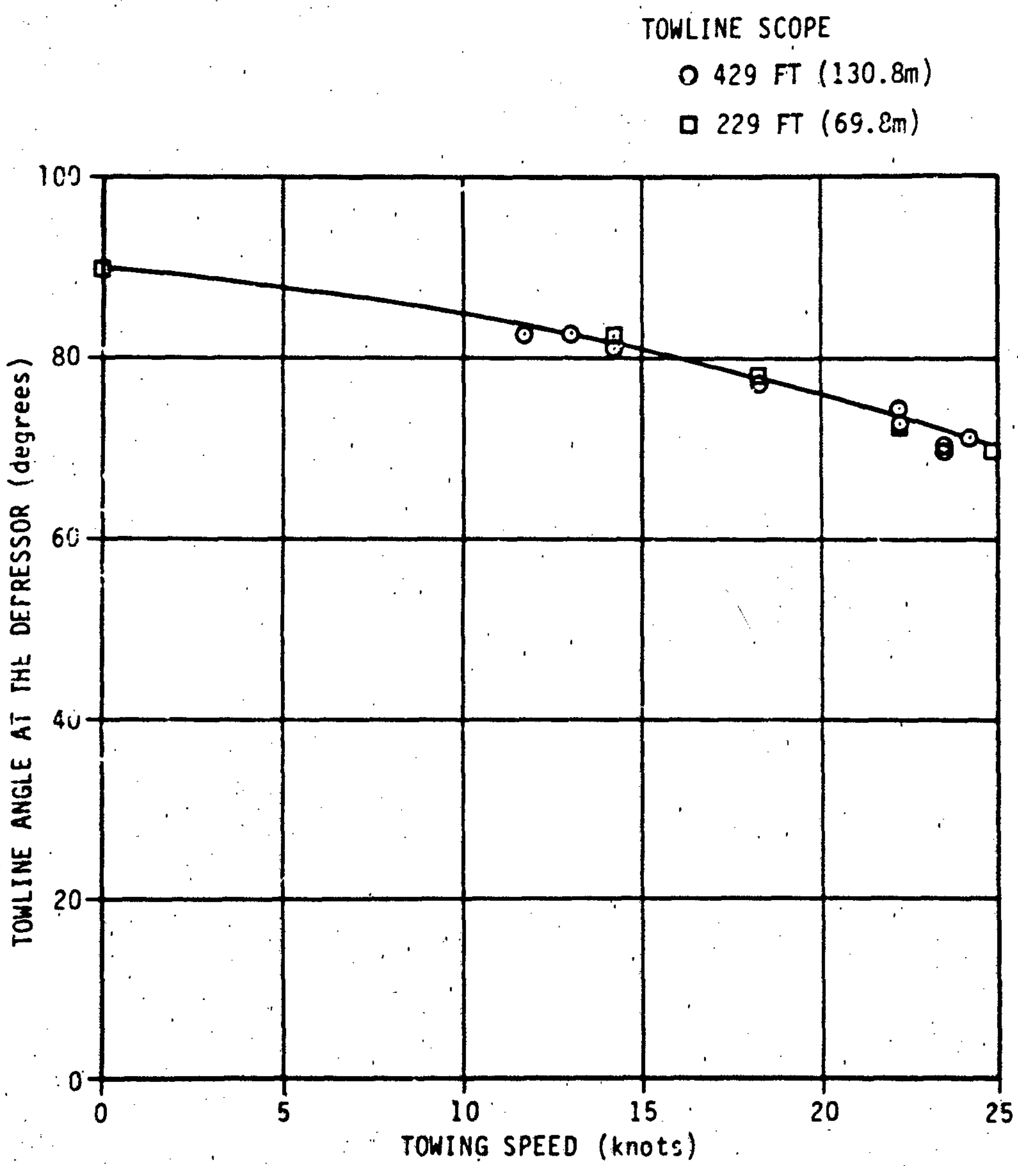

Figure 12 - Towline Angle at the Depressor as a Function of Speed

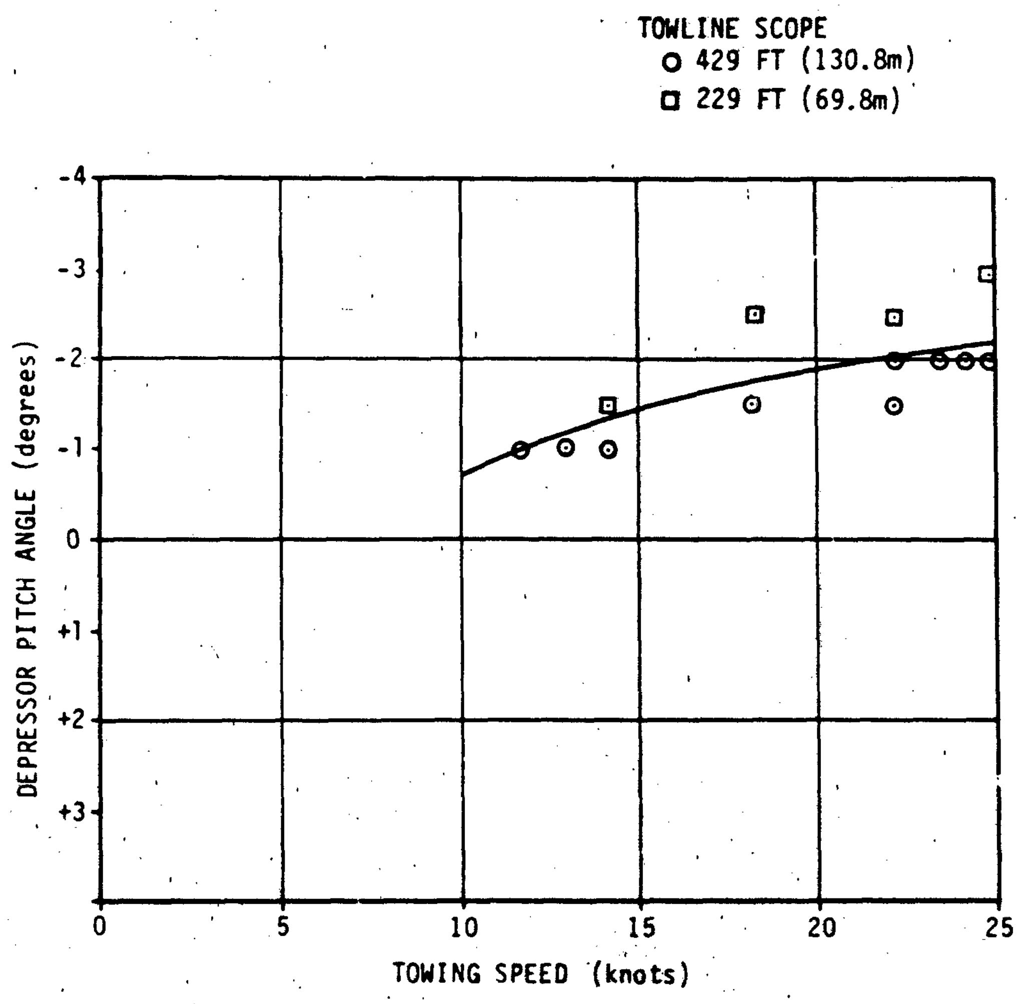

Figure 13 - Depressor Pitch Angle as a Function of Speed

Walton's loading functions for sectional fairing are:

$$f_n = -1.5716 + 1.7367 \cos\phi + 2.4064 \sin\phi \qquad [1]$$

$$-0.1651 \cos 2\phi - 0.7808 \sin 2\phi$$

$$f_t = -0.1158 + 0.4641 \cos\phi + 0.1158 \sin\phi \qquad [2]$$

where f_n and f_t are the normal and tangential loading functions, respectively, and

ϕ is the vertical towline angle with respect to the free stream (see Figure 4).

The drag coefficient C_R is defined to be,

$$C_R = \frac{R}{(1/2)\ \rho V^2 t} \qquad [3]$$

where,

R is the drag per unit of towline length when the towline is normal to the free stream (ϕ = 90 deg),

ρ is the mass density of the fluid,

V is the towing speed, and

t is fairing thickness.

The drag coefficient is assumed to be a function only of the Reynolds number. Reynolds number R_n is defined to be

$$R_n = Vt/\nu \qquad [4]$$

where ν is the kinematic viscosity of the fluid.

Various values for the drag coefficient were assumed in the analysis until a reasonable correlation was obtained between the measured and predicted towing depth.

Drag coefficient is plotted as a function of Reynolds number in Figure 14. Some scatter is apparent, but the drag coefficient appears to have a value of approximately 0.2.

Measured values for depressor depth, towline tension at the ship, and towline angle at the ship are compared to predicted values using a drag coefficient of 0.2 in Figures 15 through 17. The predictions are within the accuracy of the data.

Several types of towline fairing have been evaluated in the laboratory to determine their hydrodynamic loading functions and drag coefficients. A compilation of these results was made by Folb[3] who gave a drag coefficient for ribbon

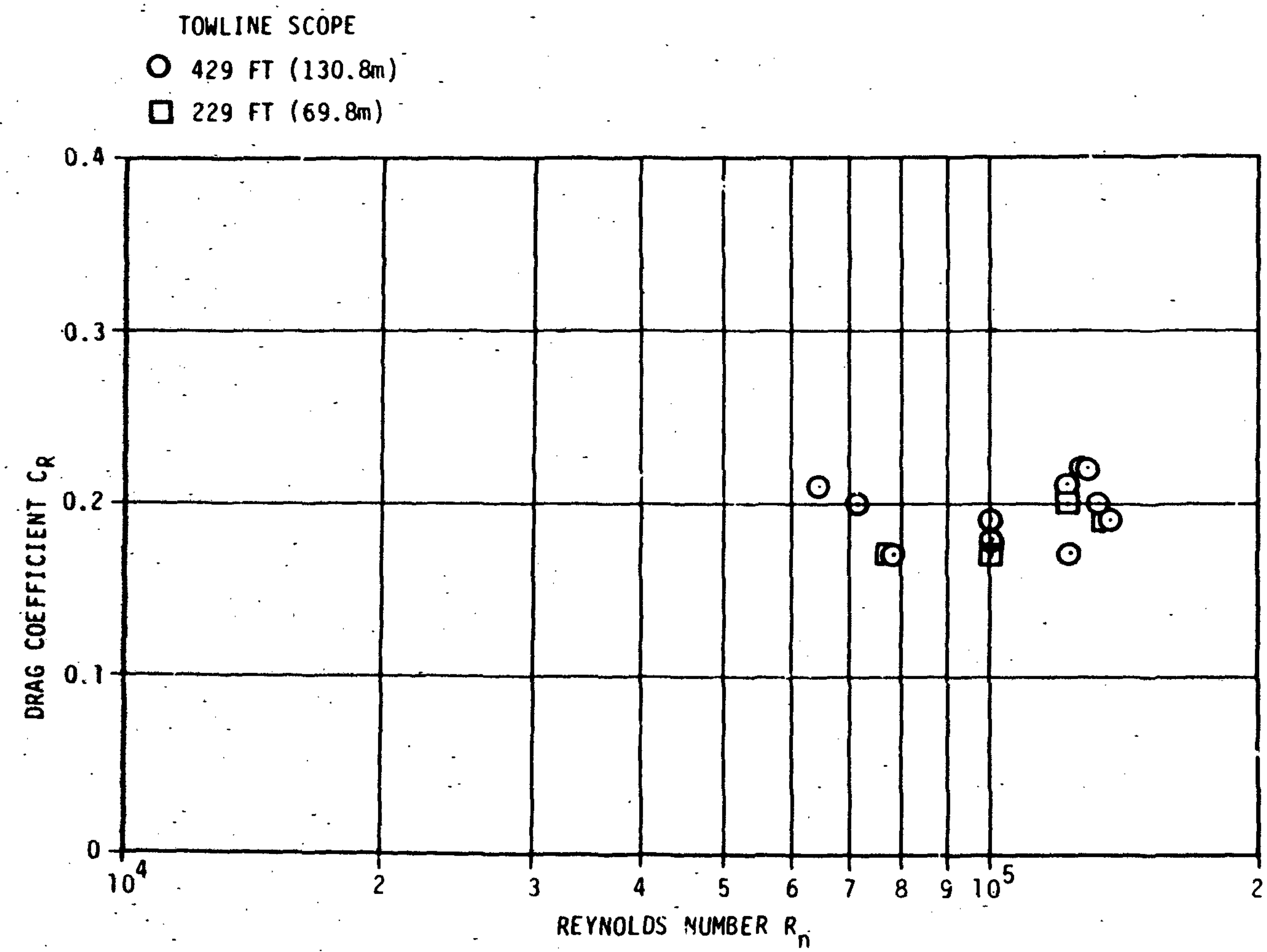

Figure 14 - Normal Drag Coefficient as a Function of Reynolds Number

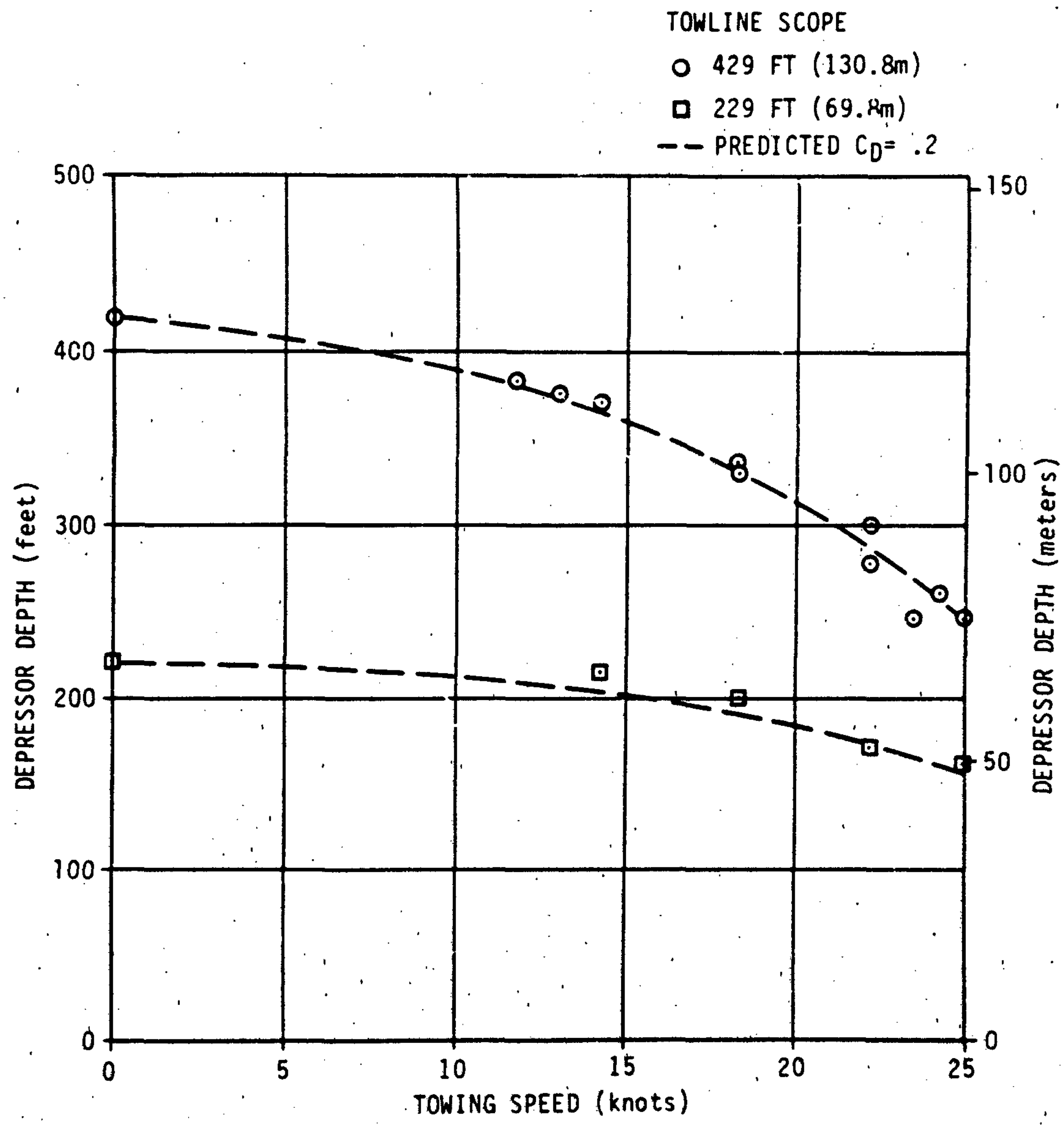

Figure 15 - Depressor Depth as a Function of Speed

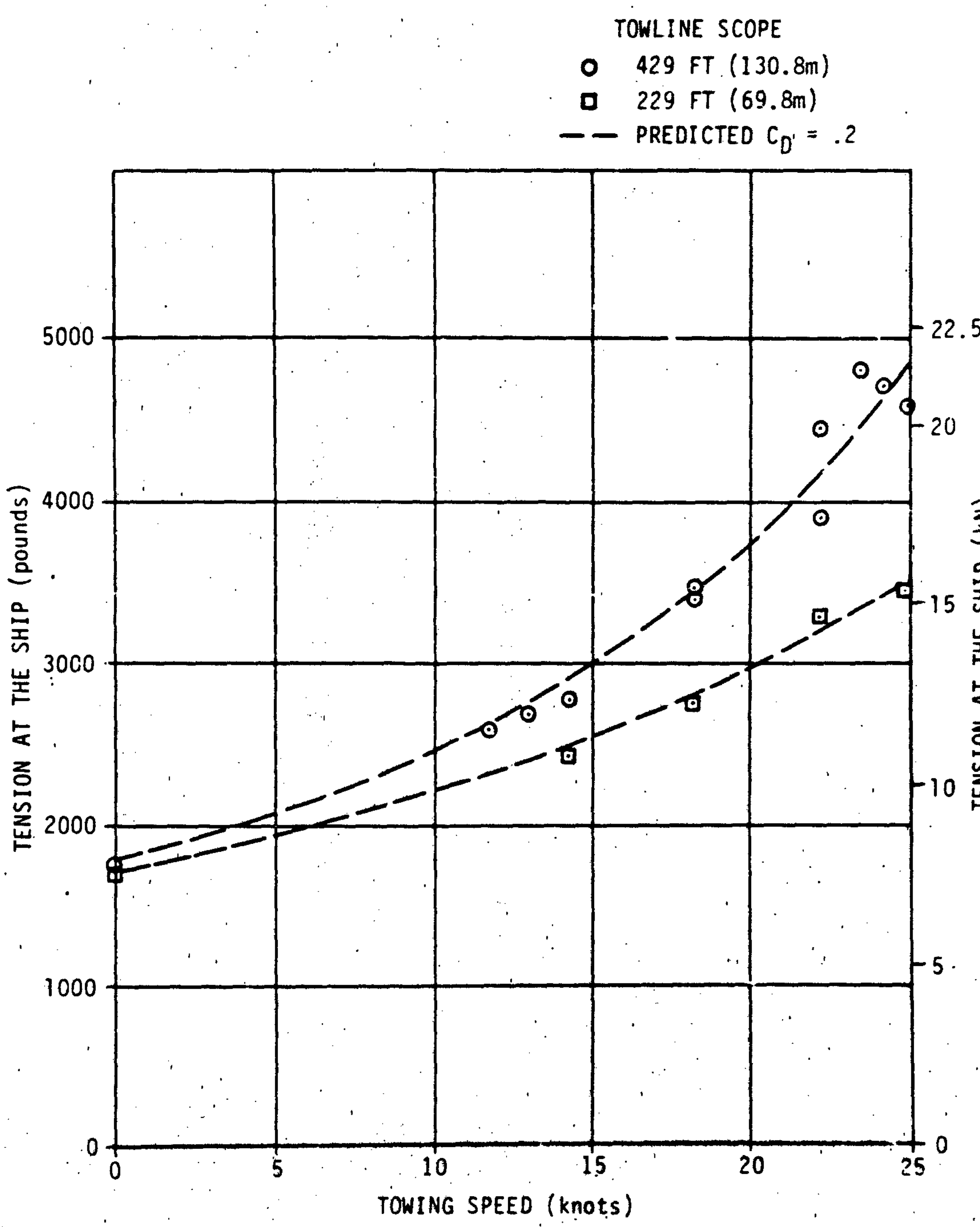

Figure 16 - Tension at the Ship as a Function of Speed

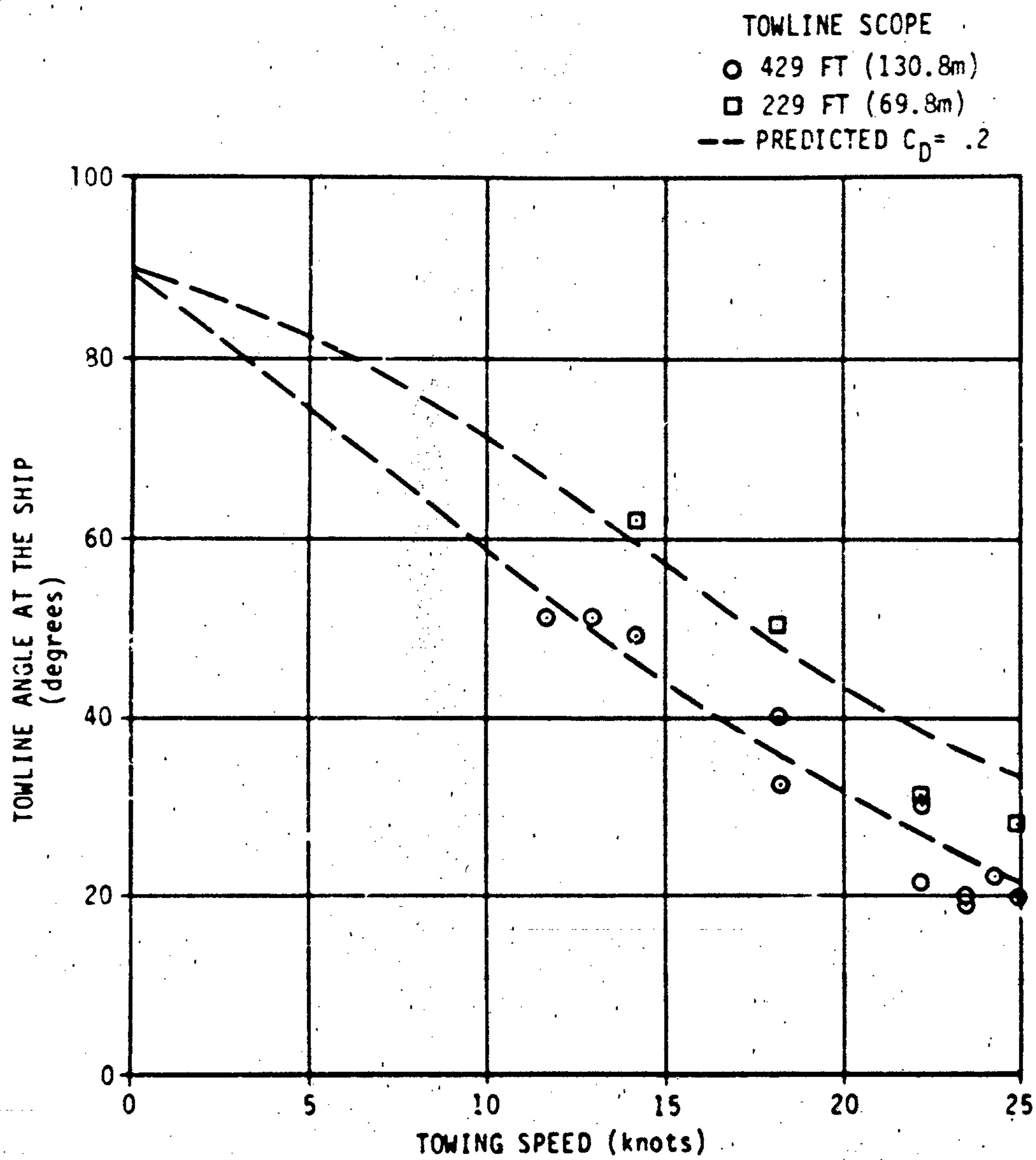

Figure 17 - Towline Angle at the Ship as a Function of Speed

fairing between 0.85 and 1.1, trailing fairing between 0.35 and 0.65, and sectional fairing between 0.1 and 0.25. The drag coefficient of 0.2 obtained for this design of Fathom Flexnose fairing is within the range of other sectional fairings that have been evaluated.

CONCLUSIONS

The tests conducted for the Flexnose lead to the following conclusions:

1. The Fathom Flexnose fairing as configured has a constant drag coefficient of 0.2 over a range of Reynolds numbers from 0.645×10^5 to 1.366×10^5.

2. The Flexnose towline will exhibit severe skew angles without fairing support rings due to stacking of the fairing sections.

3. The degree of skew can be reduced significantly by the addition of fairing support rings. The present towline exhibits acceptable skew with this addition.

4. The Fathom Flexnose fairing will sustain no damage after 4 hours of towing at 25 knots; however, durability during long-term towing is unknown.

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1. Cuthill, E. H., "A Fortran IV Program for the Calculation of the Equilibrium Configuration of a Flexible Cable in a Uniform Stream," Naval Ship Research and Development Center Report 2531 (Feb 1968).

2. Walton, C., "Experimental Determination of the Hydrodynamic Loading Functions for Sectional-Type Fairing," NSRDC Report 227-H-01 (May 1968).

3. Folb, R., "Experimental Determination of Hydrodynamic Loading for Ten Cable Fairing Models," DTNSRDC Report 4610 (Nov 1975).

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